An Account of fome Experiments on WHEEL CARRIAGES. *In a Letter from* RICHARD LOVEL EDGWORTH, *Efq*; *M.R.I.A. and F.R.S. to the Rev. Doctor* HENRY USSHER, *M.R.I.A. and F.R.S.*

DEAR SIR,

YOU may, perhaps, have experienced what I now feel in fitting down to write upon a fubject that is not likely to be interefting to many readers, and that is of fuch familiar ufe as to promife neither novelty nor material information. People imagine that they are intimately acquainted with what they have been long accuftomed to fee; and the mind feels averfe to that retrograde motion which leads it back to firft principles, when it neither fears error nor expects difcovery. Read March 1, 1788.

THE notes from which the following paper is compofed have lain by me for fome years, and the confiderations which I have juft mentioned have continually prevented me from drawing them into a connected form for publication; but what

appears

appears to me a duty, as a member of a literary academy, overcomes my reluctance, and calls upon me to contribute something, though I may be ashamed of the insignificance of my contribution.

I WAS present, in 1773, at a set of experiments that were tried in London to determine the relative advantage of high and low wheels for carriages. Disputes had arisen upon this subject between mechanics of no small eminence, and to determine them an apparatus was provided, consisting of a very long and smooth table, upon which the carriages to be compared were to be drawn by a string and a descending weight. The carriages were constructed by some of the best workmen in London; the strings were made of plaited silk of small diameters, passing over a pulley nicely turned, and mounted in such a manner as to have scarcely any friction. The experiments, however, were undecisive, each party claiming their evidence in favour of their own opinion; very little difference was perceptible between the carriages when they ran upon the smooth table; and when they were drawn over obstacles, sometimes the high and at other times the low wheels had the advantage, according to the different heights and shapes of the obstacles. It appears upon a first view that the force which drew these carriages was employed only in overcoming the friction of the axle-tree, or in lifting the weight over the obstacle. But I suspected at the time, and have been since convinced, that an obstruction of another sort existed, which was more considerable than either of those which I have mentioned, and which has not to my knowledge been taken notice of by any writer upon mechanics.

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The load upon a carriage in paffing over an obftacle refifts the power which draws it, not only by its weight, but by its vis-inertiæ; after a carriage has been once fet in motion upon a fmooth road with any given velocity, its motion, fo long as that velocity is continued, is neither retarded nor promoted by its vis-inertiæ; but whenever it paffes over any height, not only the weight of the carriage muft be lifted up, but the vis-inertiæ of that weight muft be overcome in a new direction, and as much velocity muft be communicated to it in that new direction as will enable it to rife to the height of the obftacle whilft it paffes over its bafe. When an obftacle is of fuch a fize and fhape that a wheel of fix feet diameter muft ftrike the top of it at once, and not roll from the bottom upwards, and when its fhape will permit a fmaller wheel to touch it during its whole afcent, as there is more time allowed for overcoming the vis-inertiæ of its weight in the latter cafe than in the former, the fmaller wheel may be drawn forward by a lefs power than the larger, notwithftanding the advantage of lever, which is in favour of the larger wheel.

To determine thefe circumftances by experiment, it was neceffary to conftruct an apparatus different from that which I have defcribed. I at firft made ufe of an inclined plane of five or fix feet long, and one foot high, placed upon a fmooth horizontal floor. The diftance to which the carriage was driven upon the floor by the velocity which it acquired in its defcent down this inclined plane, I affumed as the meafure of its acquired force, and the refiftance of any obftacle which I placed in its way I determined by the diminution of this diftance. But

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though I was well fatisfied with the accuracy of this mode of trial, I conftructed another that might appear to others lefs liable to objection.

I SCREWED a circle of iron three feet three inches diameter upon a folid floor; in the centre of this circle I erected an upright axis or roller upon two pivots, one refting in a focket of brafs upon the floor, the other in a bridge which was raifed acrofs the machine. This axis or roller had a fmall filk cord wound round its circumference, which paffing into an adjoining ftaircafe, had a fcale and weights tied to it, which turned the roller with the required velocity. From the roller a horizontal arm of wood extended to the circumference of this iron circle, and to its extremity was faftened a piece of fteel in the form of an axle-tree of a carriage, and upon this was placed a wheel, which by thefe means was carried round upon the brafs circle, as the ftone of tanners bark-mill moves round the trough which belongs to it. This arm was permitted to move up and down by means of a hinge, fo as to let the wheel rife over any obftacle which was placed in its way. Befides this another arm was placed above that which carried the wheel, at the extremity of which was faftened a piece of tin, forming a vane, which, by its refiftance to the air, regulated the motion of the machine. The roller was now made to turn by putting weights into the fcale, and it was let to revolve until its motion became uniform. After eight or ten turns it revolved with an equable velocity; and during every fet of experiments the fame velocity was preferved, and whatever refiftance the carriage was expofed to was overcome by the addition of weight. The additional weight became

became therefore, in all cafes, the meafure of the additional refiftance, and determined with the greateft accuracy the refult of every experiment which I wifhed to try.

HAVING found that nearly five pounds and a half was fufficient to give the wheel, when loaded fo as to weigh about four pounds, a velocity of nearly ten feet in a fecond, I placed an obftacle of a quarter of an inch high upon the plane, and it required no lefs than fix pounds and a half to overcome its refiftance. Two fuch obftacles required fourteen pounds and a half. Two obftacles of the fame height, but of a different fhape, each making an inclined plane of three quarters of an inch long and a quarter of an inch high, were fubftituted in the place of the former, and it required but two pounds to overcome their refiftance. The difference, therefore, between two and fourteen muft be attributed to vis-inertiæ; for the velocities of the carriage and the heights of the obftacles remaining the fame, the only difference that exifts is, that in the one cafe the wheel has much more time to furmount the obftacle than in the other, and confequently had much lefs vis-inertiæ to overcome.

FROM this confideration it appears that whatever permits the load to rife gradually over an obftacle, without obftructing the velocity of the carriage, will tend to facilitate its draught; and the application of fprings has this effect to a very confiderable degree. The fame weight of four pounds being drawn over the fame obftacles, when fprings were put between the load and the carriage, by four pounds inftead of fourteen.

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This remarkable difference points out the great advantage of ſprings in rough roads; an advantage which might be obtained for heavy waggons as well as for other carriages by a judicious application of the ſame means.

It has but ſeldom happened that the modeſty of theory has promiſed leſs than what has been verified by experiment; but it appears from the Memoirs of the French Academy that the idea of applying ſprings to carriages had occurred to Monſieur Thomas in the year 1703, who has given a drawing of a carriage conſtructed upon this principle many years before it was attempted to be put into execution. So little hope had he entertained of ſucceſs, that he expreſsly mentions it as a theory which could not be reduced to practice; he had, however, no notion of applying ſprings to facilitate the draught, but merely for the convenience of the rider; and I apprehend that it is not at preſent commonly imagined that ſprings are advantageous for this purpoſe; nor would it at firſt ſight appear credible, that upon a rough paved road, ſuch as are common in Cheſhire and other parts of England, a pair of horſes could draw a carriage mounted upon ſprings with greater eaſe and expedition than four could draw the ſame carriage, if the ſprings and braces were removed, and the carriage bolted faſt down to the perch. I tried ſome other experiments with the ſame apparatus to compare long and ſhort, high and low carriages. I have loſt the particular reſults of each experiment, but I am well aſſured that the preference which has lately been given in England to high carriages is ill-founded; that upon ſmooth roads the height of the carriage is a matter of indifference as to the draught, and that in rough roads it is conſiderably

confiderably difadvantageous; that the length of carriages, if their weight be not encreafed, is alfo a matter of indifference, except in very uneven roads, and where there are deep ruts; in the former long carriages are preferable, in the latter fhort ones.

I SUBJOIN a drawing of the apparatus which I made ufe of in thefe experiments, and a table of the experiments, from which the mechanic may draw many ufeful obfervations, and which may fupply the mathematician with many curious and elegant fubjects of inveftigation.

Your's, &c.

R. L. E.

TABLE.

The weight of the load 3 lb. The weigh
The ſcale and weight deſcended ſix inche
The diameter of the wheel was two incl

	EXPERIMI
1	A vane of tin, 11 inches long, and 5 an arm, projecting from the roller, the machine by its reſiſtance againſ the vane 21 inches from the centre of
2	The ſame as No. 1, with the wheel circle - - - - -
3	The ſame as No. 2, but with an obſta on the road - - - -
4	The ſame as No. 2, but with two obſta
5	Ditto, with two inclined planes, ¼ inch of the obſtacles - - -
6	Springs placed between the weight and ¼ inch high, placed on the road -
7	Same as No. 1, with half the velocity
8	Same as No. 4, with half the velocity
9	Same as No. 6, with half the velocity

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d 3 lb. The weight of the load, wheel and carriage, &c. 4lb.
descended six inches and two-tenths every revolution of the roller.
wheel was two inches nine-tenths, and the circumference of the circle upon which

EXPERIMENTS.	*Turns.*	*Time.*	*Weight.*			
		Seconds.	lb.	oz.		
nches long, and 5 and $\frac{1}{4}$ broad, fastened to g from the roller, to regulate the motion of its resistance against the air; the extremity of s from the centre of the roller, made -	20	20	4	10	1	The resist moving This we in the fi
ɪ, with the wheel running upon the iron - - - - - - -	20	20	5	10	2	4 lb. 10 oz 5 lb. 10 motion
, but with an obstacle of $\frac{1}{4}$ inch high, placed - - - - - - -	20	20	12	0	3	The resista
but with two obstacles - -	20	20	20	0	4	The resista
ined planes, $\frac{1}{4}$ inch high, $\frac{3}{4}$ inch long, instead - - - - - -	20	20	7	8	5	The resista
een the weight and the wheel, two obstacles d on the road - - - -	20	20	9	8	6	The resist used, or
half the velocity - - -	10	20	1	6	7	Resistance
half the velocity - - -	10	20	7	8	8	Resistance
half the velocity - - - -	10	20	3	8	9	Resistance

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circle upon which the wheel ran was ten feet three inches and a quarter.

ight. oz.		OBSERVATIONS.	lb.	oz.
10	1	The refiftance of the air againft the vane, and againft all the moving parts of the machine, was equal to - - - This weight muft therefore be deducted from the weights ufed in the fubfequent experiments.	4	10
10	2	4 lb. 10 oz. being deducted for the refiftance of the air from 5 lb. 10 oz. the remainder was the refiftance occafioned by the motion of the wheel on the fmooth board - -	1	0
0	3	The refiftance of an obftacle of $\frac{1}{4}$ inch high - -	6	6
0	4	The refiftance of two obftacles of $\frac{1}{4}$ inch high - -	14	6
8	5	The refiftance of inclined planes inftead of abrupt obftacles -	1	14
8	6	The refiftance of two obftacles $\frac{1}{4}$ inch high when fprings were ufed, only - - - - - -	3	14
6	7	Refiftance of the air to half the former velocity - -	1	6
8	8	Refiftance of two obftacles with half the former velocity -	6	2
8	9	Refiftance of ditto with fprings - - - -	2	2

ten feet three inches and a quarter.

V A T I O N S.	lb.	oz.
ainſt the vane, and againſt all the ıe, was equal to - - - be deducted from the weights uſed ıts.	4	10
for the reſiſtance of the air from was the reſiſtance occaſioned by the ; ſmooth board - -	1	0
of $\frac{1}{4}$ inch high - -	6	6
ɛs of $\frac{1}{4}$ inch high - -	14	6
ıes inſtead of abrupt obſtacles -	1	14
les $\frac{1}{4}$ inch high when ſprings were - - - -	3	14
he former velocity - -	1	6
th half the former velocity -	6	2
ςs - - - -	2	2